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AUTHOR Hay, J. E.; And Others
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ABSTRACT

This unit is one of a group of units written to fit the Certificate of Sixth Year Studies (CSYS) chemistry course, but it could be used in most Sixth Form courses. The format for this unit is a decision-making or role playing situation. It includes: (1) background information for the teacher, with descriptions of the three roles for individuals or small groups (the roles are those of an industrialist and two consultants), suggested guidelines for two class sessions, and expected answers for student decision sheets; (2) a consultant's packet with references on the chemical urea (instructions, background papers, data sheets, and summary sheets); (3) a consultant's packet with references on ammonium nitrate; and (4) a packet with references related to industry. This situation provides for an industrialist to seek advice on whether to convert the present ammonia for which he already has a plant into ammonium nitrate or into urea. The interaction of students, based on their knowledge of chemistry and other disciplines, should aid in understanding that decisions in the chemical industry are multidisciplinary. (DH)

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NITROGEN FOR THE NINETIES

This unit is one of a group of units written to fit the Certificate of Sixth Year Studies course but could certainly find a place in most Sixth Form courses.

The series has been written by a group of teachers, college lecturers, university lecturers and industrialists.

It has been supported financially by the Education Appeal Fund of the Royal Society of Chemistry and the Education for the Industrail Society Group of the Scottish Curriculum Development Service and has received the approval of the Chemistry Panel of the Scottish Examination Board.

It is hoped that this will be used in an interactive way to give pupils the experience of making decisions for themselves on the basis of their chemical knowledge and the knowledge of other disciplines, so that they may truly see that the decisions of chemical industry are of necessity - multi disciplinary.

We realise that this unit will not be perfect and we would welcome helpful criticism so that later editions can be improved.

Dr. A.H. Johnstone
General Editor.

The writers of this unit were:-

Dr. J.E. Hay, Moray House College of Education, Edinburgh. (Convenor).

Dr. A. Watson, Currie High School, Currie, Midlothian.

Dr. D. Pritchard, Stevenson College, Edinburgh.

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FORMAT Decision making/role playing

TIME Two periods in class; more effective if time allowed for private study prior to class discussion.

NO. OF PUPILS Minimum of 3 (2 if teacher takes one part), can be extended to at least 8.

OUTLINE Urea competes directly with ammonium nitrate as a fertiliser and its importance has increased rapidly over the past twenty years, particularly in the developing countries.

Three pupils (or three small groups) act respectively as:-

A U.K. industrialist seeking advice about whether to convert ammonia (for which he already has a plant) into ammonium nitrate or urea.

Two consultants, one of whom will advise on ammonium nitrate production and the other on urea.

Session 1. The industrialist prepares questions to ask his consultants and acquires some background information on nitrogen fertilisers. All essential information for this is supplied.
The industrialist's papers (blue) comprise:-

- an instruction sheet
- Background Sheet 1 'Production and Marketing Problems' (a general outline only, no data on ammonium nitrate or urea)
- Background Sheet 2 'Action of nitrogenous fertilisers' (2 pages)
- Decision Sheet (3 pages)

The consultants prepare the case for ammonium nitrate and urea respectively. Each consultant has a full set of data on one of the fertilisers plus selected disadvantages of the other to provide him with ammunition against his competitor. Each consultant must present his case in as favourable a light as possible by selection of appropriate data. He will have to defend himself against the criticisms of the other consultant and allay the anxieties of the industrialist. Both fertilisers have their advantages and disadvantages and so each consultant has a genuine case.

The consultants' papers comprise:-

NH_4NO_3 (Green)
- an instruction sheet
- 5 Data Sheets
- 3 Background Papers (photocopies of relevant information, little extra reading involved)
- Summary Sheet (2 pages) to assist in preparation of report

Urea (Yellow)
- an instruction sheet
- 5 Data Sheets
- 3 Background Papers
- Summary Sheet (2 pages)

If pupils are working singly this preparation session could be done outwith class time.

Session 2. The industrialist meets his two consultants together, puts his questions to them and finally decides which of the two fertilisers he thinks he should make.

A copy of the industrialist's Decision Sheet, tentatively completed, is on pp3 and 4 of the Teachers' Guide.

Notes:

1. No additional material is necessary but if the 'industrialist' is enthusiastic and has the time he may wish to do some extra reading in the first session on the chemistry of fertilisers in standard organic and inorganic text books.

2. If there are only two pupils in the class, the teacher could take the industrialist part.

3. There is scope for two pupils in the industrialist role and two or three in each consultant role. For larger classes it might be better to duplicate the exercise with several small groups of pupils and it would be interesting to see whether all the industrialists came to the same decision.

4. The choice of an articulate pupil as the industrialist contributes to the success of the exercise.

DECISION SHEET

The following is an indication of what pupils might be expected to enter on the Decision Sheet. Their entries need not, of course, conform to this example.

Questions	NH_4NO_3	Urea	Decision
Production			
Extra plant	HNO_3 & NH_4NO_3	Urea	Urea (simpler)
Raw materials	NH_3, air, water, Pt catalyst	NH_3, CO_2 (CO_2 a by-product of NH_3 process)	Urea (cheaper)
Energy requirements	3.2 GJ/ton = 9.1 GJ/ton N	3.8 GJ/ton = 8.1 GJ/ton N	Urea
Purity of product	No problem	Toxic biuret, but formation can be easily controlled.	NH_4NO_3 ?
Pollution problems	Oxides of N from HNO_3 NH_4NO_3 particles into air - must be controlled.	Urea particles into air, must be controlled.	Urea ?
Outlet for intermediates	Other uses for HNO_3	-	NH_4NO_3
Transport and Storage			
Safety	Explosion hazard; little problem if storage regulations observed.	No problem	Urea
Cost	Bulkier than urea (only 35% N, urea 46% N)		Urea

Decision Sheet contd.

Questions	NH_4NO_3	Urea	Decision
Action as fertiliser	NO_3^- immed. available $NH_4^+ \longrightarrow NO_3^-$	Delay in production of NO_3^-, but held near roots. Possible loss of NH_3 to the air in alkaline soils (U.K.)	? (left to pupils)
Pollution problems	Possible NO_3^- pollution of water supplies, not serious U.K.	No leaching	
Present market			
Share of world market	About 25%	About 25%	Either
Demand	Steady for a long time, but dropping slightly.	Increasing rapidly, but can this continue?	? (left to pupils)
Use in diff. world regions	Favoured in W. Europe	Highly favoured in rice-growing countries	? (left to pupils)
Price	£110 per ton = £314 per ton N	£158 per ton =£339 per ton N	NH_4NO_3 ?
Future market	W. Europe looks safe.	Export to developing countries looks tempting but they may start their own production or import from nearer developed countries.	? (left to pupils)
Alternative uses	Explosives	Cattle-feed Plastics Drugs	Urea

Decision by section

1. Production: Urea?
2. Transport & storage: Urea
3. Action as fertilisers: ?
4. Present market: ?
5. Future market: ?

} left to pupils

FINAL DECISION.

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NITROGEN FOR THE NINETIES

UREA

Consultants Paper

INSTRUCTIONS TO UREA CONSULTANT

You have been employed by a U.K. industrialist to give advice on the conversion of ammonia (which the industrialist is already producing) into UREA for sale as a fertiliser. The industrialist is also seeking advice from a second consultant on the conversion of ammonia into the fertiliser AMMONIUM NITRATE.

Session 1

You are provided with data on the manufacture, transport, use and market potential of urea. The industrialist does not have any of this data - this is what you are being paid to provide. Study the data carefully and select the advantages of your compound so that you can put a favourable case for urea production to the industrialist when you meet him in the next session. You must be ready to answer his questions and you will have to admit to the disadvantages of your compound if you are asked about them, but be prepared to minimise them.

You are also provided with some ammunition against the ammonium nitrate consultant in the form of the main disadvantages of his compound. (This means that he knows the disadvantages of yours!) Use this information to challenge the ammonium nitrate consultant in front of the industrialist. You may score some points but be prepared to defend yourself when you are challenged.

You may wish to use the accompanying Summary Sheet to help you organise your report for the industrialist.

Session 2

You and the ammonium nitrate consultant meet with the industrialist and put your cases before him. He will decide which compound he wants to make. His decision depends largely on how good a case you can make as both ammonium nitrate and urea have advantages and disadvantages in their production and use as fertilisers.

PRODUCTION

Manufacturing process

$CO_2(g) + 2\ NH_3(g) \longrightarrow NH_2CONH_2(s) + H_2O(l)$

Raw materials: NH_3, CO_2 - which is a byproduct of the NH_3 process

N.B. During the final concentration of the urea solution biuret forms as an impurity.

$$2\ NH_2CONH_2 \rightleftharpoons \underset{\text{biuret}}{H_2NCONHCONH_2} + NH_3$$

Biuret is toxic and harmful to some crops.
Its presence in fertiliser grade urea must be below 1%
The production process has been so designed that this is easily achieved in commercial production.

Energy requirements of manufacture

Solid urea 3.8 GJ per ton (1gigajoule = $1x10^9$J)

> Challenge NH_4NO_3 consultant:
>
> Wherever quantitative data are quoted for ammonium nitrate and urea it is to your advantage to point out the relative percentages of nitrogen in the two compounds.
> Work them out now. You can use them here and later.

Pollution problems in manufacture

Urea particles emitted into air.
This is serious and must be controlled.

(See Monsanto advertisement, Background Paper 1)

TRANSPORT AND STORAGE

Urea is inert and non-explosive

Challenge NH_4NO_3 consultant:

1. safety - confront him with the newspaper report Background Paper 11.

2. transport costs - his product is bulkier (use % N and see Background Paper 111, Diagram A)

ACTION AS FERTILISER

N is only of use to the plant once in the form of NO_3^-

Conversion of urea to NO_3^-:-

(i) Hydrolysis $NH_2CONH_2 \xrightarrow[\text{in soil}]{\text{enzyme UREASE}} (NH_4)_2CO_3$

(ii) Nitrification $NH_4^+ \xrightarrow[\text{in soil}]{\text{nitrifying bacteria}} NO_3^-$

Possible loss of N to the air

Ammonium carbonate is unstable and under certain conditions ammonia gas may be lost into the air with consequent loss of fertiliser N. This depends on

a) the pH of the soil - the more alkaline the soil, the more readily is ammonia evolved.

b) the rainfall. Provided that urea has been washed into the soil ammonia will not be lost.

The success of urea in rice-growing countries is due to more acidic soils and adequate moisture to wash in the applied urea.

Its performance in the U.K. where soils tend to be alkaline, is more variable although never less than about 90% of the efficiency of other nitrogen fertilisers.

Behaviour in soil of N compounds

1. Nitrates are very soluble and easily washed out of soil (leached): leaching can cause pollution (eutrophication) of water courses due to high nitrate content.

2. Ammonium compounds are not leached. The ammonium ion is held in the soil by adsorption on clay particles.

3. Urea is almost as soluble as nitrate, but the hydrolysis reaction stops leaching since it converts urea into an ammonium salt. This is an advantage of urea - it moves quickly into the root zone by leaching but is then held there as hydrolysis occurs. (See Background Paper 111, Diagram B).

Challenge NH_4NO_3 consultant:

Leaching of nitrate and consequent pollution problems.

MARKET

Selling price

£158 per ton of urea (July 1981, U.K.)

> Challenge NH_4NO_3 consultant:
>
> What about relative prices per ton of nitrogen?

Market Use

Urea consumption is growing rapidly mostly due to its suitability as a rice fertiliser.

Market data

Production and consumption data are given on Data Sheet 5. For purposes of comparison both you and the ammonium nitrate consultant have the same data.

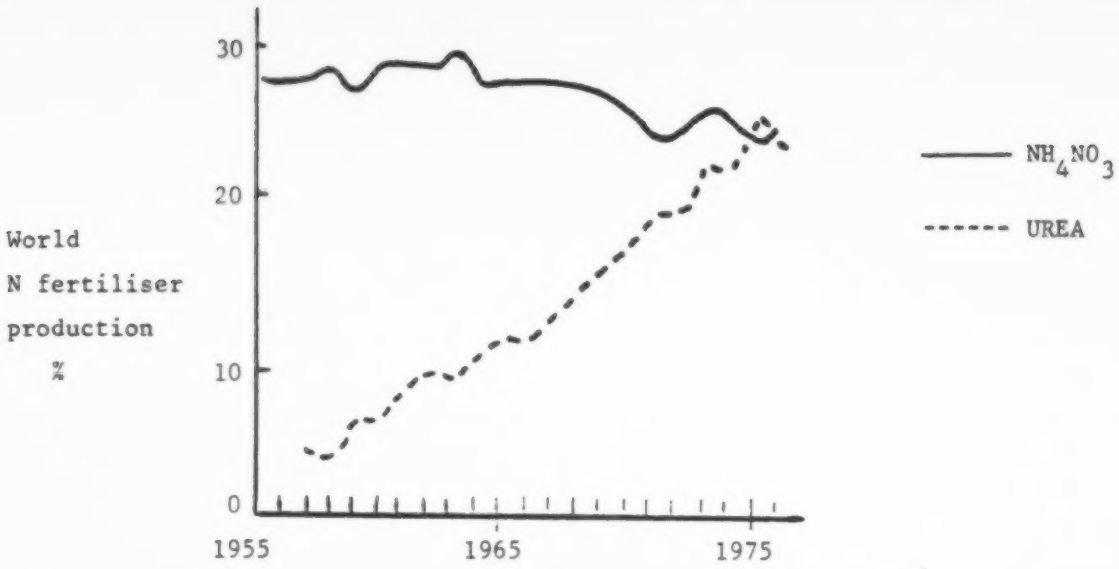
Study the data and prepare a brief summary for the industrialist. Do not overwhelm him with figures but try to provide him with the following information about urea:-

- its share of world nitrogen fertiliser production
- consumption trends (increasing/steady/decreasing)
- geographical variations in its use which support your case
- future market

Market outlets other than as fertiliser

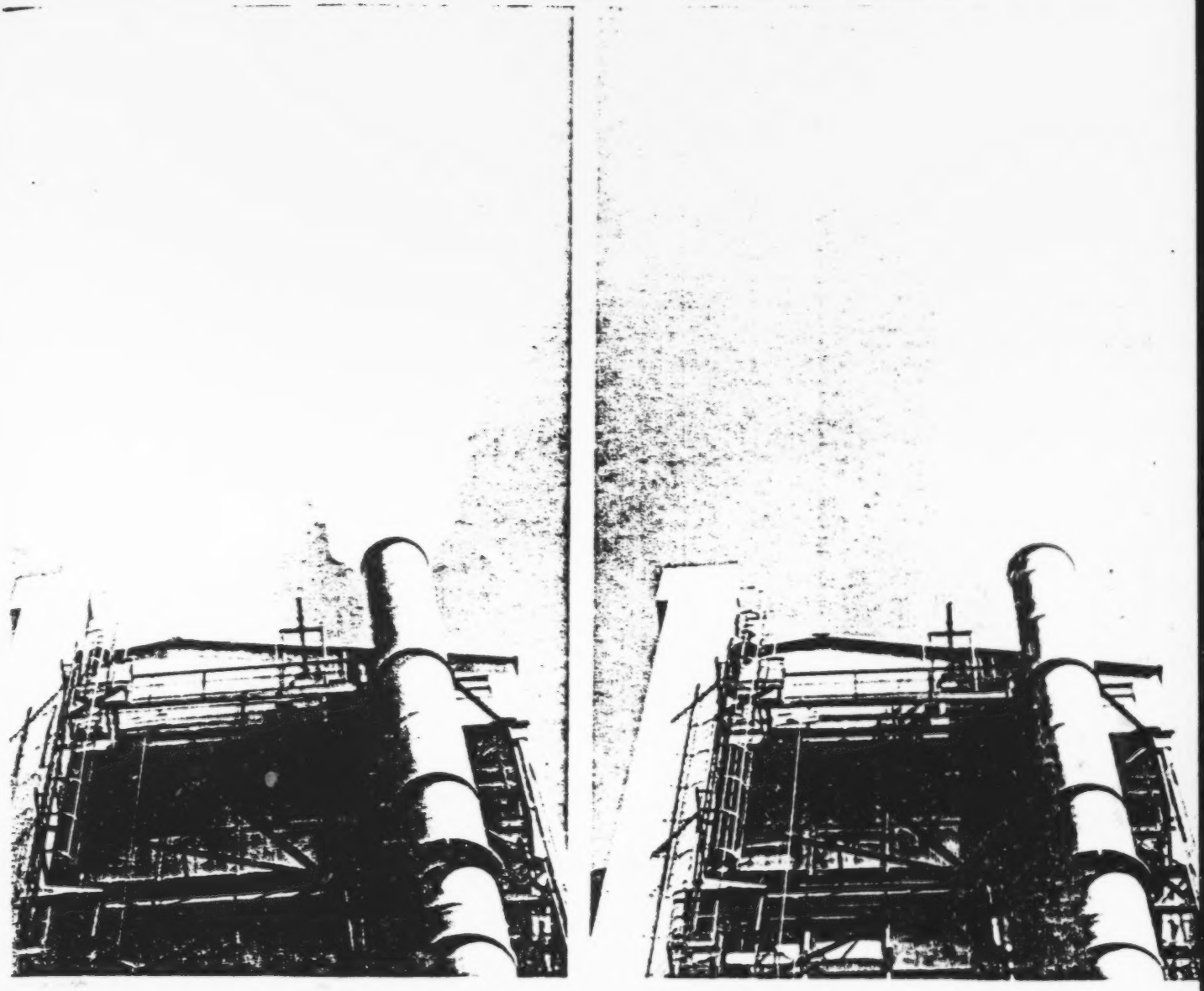
% of total urea output	
15	used for plastics (urea-formaldehyde resins) and drugs (barbiturates)
10	used for a cattle-feed supplement.

The use of urea as a cattle-feed supplement is growing in importance and is an attractive outlet as it also involves the agricultural industry.



World region	Country		1975-76 '000 tonnes N Prodn	Cons	1978-79 '000 tonnes N Prodn	Cons
West Europe	Belgium-Lux	A.N..	199	106	243	114
		Urea		3		0.5
	Denmark	A.N.	23	23	26	26
		Urea		1		3
	Nether-lands	A.N.	437	378	424	368
		Urea	342	1.5	468	0.7
	Italy	A.N.	168	154	202	178
		Urea	372	197	641	335
*	U.K. All N fertilisers		1055	1045	1147	1222
North America	U.S.A.	A.N.	1147	901	1032	765
		Urea	854	662	1090	877
Latin America	Brazil	A.N.	76	76	107	110
		Urea	24	81	33	197
Far East	India	A.N.	155	182	140	161
		Urea	1011	1342	1521	2224
	Pakistan	A.N.	18	22	21	19
		Urea	278	353	286	531

All figures from the F.A.O. Fertiliser Yearbook 1979.
Where there are blanks no figures are available.
* Breakdown figures for U.K. are not available but the bulk of U.K.'s nitrogen fertilisers is based on ammonium nitrate.



When material costs are rising sky-high, the benefits of Monsanto Mist Eliminators are clear.

The exhaust plume on the left is more than just unsightly. It's downright wasteful.

Fortunately, there's a simple solution. The same stack is shown on the right, fitted with Monsanto Mist Eliminators.

Installing Monsanto Mist Eliminators has a dramatic effect on the exhaust of process gas in ammonium nitrate and urea plants.

Air pollution control is a further benefit. Plumes become virtually invisible, and emissions are easily within statutory limits.

Find out how Monsanto can tailor a Mist Eliminator system to your requirements. Contact Enviro-Chem Systems Dept., Monsanto Europe S.A., 270-272 Avenue de Tervuren, 1150 Brussels, Belgium. Tel:(02)-762.11.12. Telex 62927.

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Monsanto Enviro-Chem

"The Glasgow Herald" April 17 1947

1200 FEARED DEAD IN EXPLOSION

American City Devastated When Ship Blows Up

POISONOUS GASES SWIRL THROUGH STREETS

In what has been described as one of the major disasters in the U.S., 1200 people are stated to have been killed and over 1000 injured when explosions yesterday wrecked a large part of Texas City.

Five hundred bodies have been removed from the explosion area and more are being found continually, the Mid-Western Red Cross Headquarters reported last night.

The first explosion took place on board the cargo ship, Grand Camp, stated to have a cargo of ammonium nitrate, which caught fire and blew up when being towed away from the dockside.

This was followed by a series of explosions in the town, one of which wrecked a large chemical plant, while others set fire to 50 oil storage tanks. Explosions were still occurring early this morning.

Many of the killed and injured had gathered at the dockside earlier in the day to see the burning ship and faced the full force of the first explosion. Poisonous gases from the ship also took their toll.

In Texas City and Galveston, 12 miles away, all windows were shattered, roofs of houses collapsed, and buildings were cracked from top to bottom. A steel beam from the ship was found 15 miles away. The explosions also disrupted the town's water services and hampered firemen trying to put out fires at numerous points. People at Galveston saw a mushroom of smoke resembling atom bomb pictures hanging over the area.

Two occupants of a private 'plane flying over the scene at the time of the explosion were killed when the 'plane, rocked by the blast, crashed. New York [illegible] reported.

Eye-Witness Accounts

Mr W. H. Sanberg, vice-president of the Texas City Railway Company, said that while the ship was understood to be at Texas City to take on a cargo of fertiliser, "I feel sure that I am safe in saying that it did carry ammunition."

Mr Sanberg, who said he had left the Grand Camp five minutes before the blast, was severely injured by the explosion.

He gave the first eye-witness account of the disaster. He said that the ship was discovered ablaze early yesterday. Steam was applied, but failed to extinguish the fire. The ship was then taken in tow, but before she got far the explosion occurred.

A press photographer who flew over the area, said—"I've been on many raids during the war when we did less damage."

Mr Fred Pool, Laporte, said: —"The devastation here is the most terrible thing you ever saw. You can't imagine it. As I speak over a telephone) I feel there are thousands of dead and injured."

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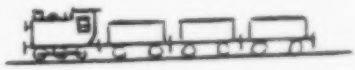
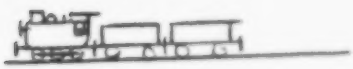
DIAGRAM A

Conveyance of 10 tonnes of pure nitrogen in the form of:



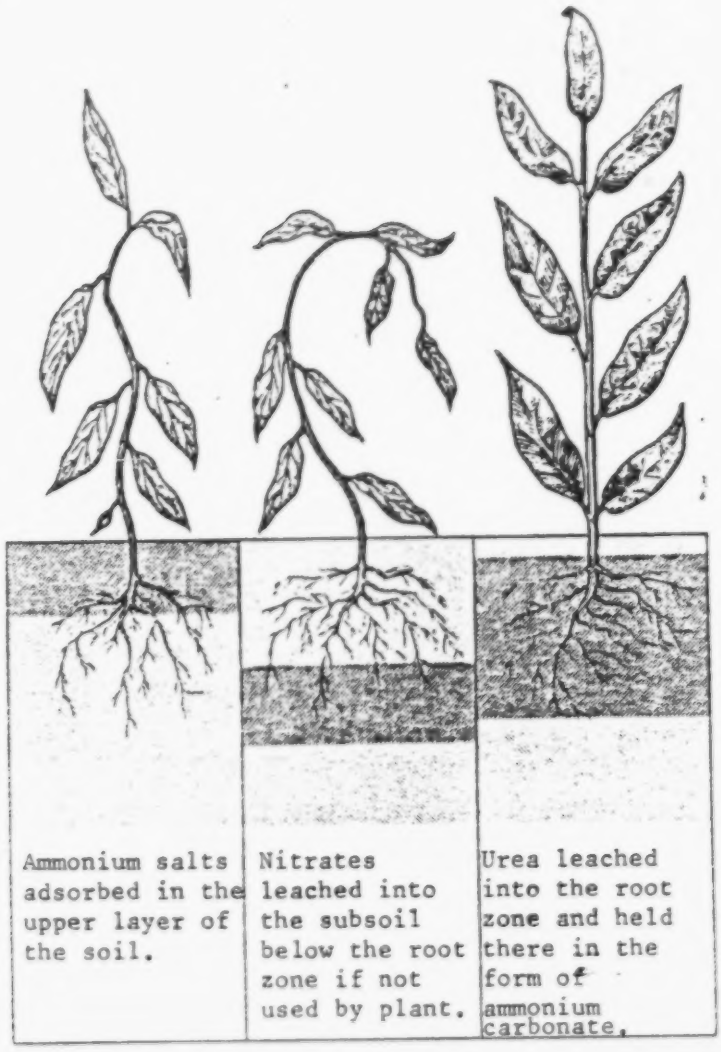
Ammonium nitrate



Urea

= 10 tonnes of fertiliser

DIAGRAM B


Ammonium salts adsorbed in the upper layer of the soil.
Nitrates leached into the subsoil below the root zone if not used by plant.
Urea leached into the root zone and held there in the form of ammonium carbonate.

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SUMMARY SHEET

CONSULTANT

Use this sheet to help you organise your report for the industrialist

	My compound	Points to take up with the opposition
Production		
Transport and storage		

Summary Sheet contd

CONSULTANT

	My compound	Points to take up with the opposition
Action as fertiliser		
Present market		
Future market		

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NITROGEN FOR THE NINETIES

Ammonium Nitrate Consultants Paper

INSTRUCTIONS TO AMMONIUM NITRATE CONSULTANT

You have been employed by a U.K. industrialist to give advice on the conversion of ammonia (which the industrialist is already producing) into AMMONIUM NITRATE for sale as a fertiliser. The industrialist is also seeking advice from a second consultant on the conversion of ammonia into the fertiliser UREA.

Session 1

You are provided with data on the manufacture, transport, use and market potential of ammonium nitrate. The industrialist does not have any of this data - this is what you are being paid to provide. Study the data carefully and select the advantages of your compound so that you can put a favourable case for ammonium nitrate production to the industrialist when you meet him in the next session. You must be ready to answer his questions and you will have to admit to the disadvantages of your compound if you are asked about them, but be prepared to minimise them.

You are also provided with some ammunition against the urea consultant in the form of the main disadvantages of his compound. (This means that he knows the disadvantages of yours!) Use this information to challenge the urea consultant in front of the industrialist. You may score some points but be prepared to defend yourself when you are challenged. You may wish to use the accompanying Summary Sheet to help you organise your report for the industrialist.

Session 2

You and the urea consultant meet with the industrialist and put your cases before him. He will decide which compound he wants to make. His decision depends largely on how good a case you can make as both ammonium nitrate and urea have advantages and disadvantages in their production and use as fertilisers.

PRODUCTION

Manufacturing process

1 Ostwald process:
Catalytic oxidation of ammonia to nitric acid.

Raw materials: NH_3, air, water, Pt catalyst

11 $NH_3 + HNO_3 \longrightarrow NH_4NO_3$

N.B. Surplus nitric acid can be used for other purposes:-

Production/consumption data

75% nitric acid produced used for fertilisers
25% " " " " " explosives, nylon, dyestuffs.

> Challenge urea consultant:
> During production of urea, biuret is formed as an impurity
>
> $2\ NH_2CONH_2 \rightleftharpoons H_2NCONHCONH_2 + NH_3$
>
> Biuret is toxic and harmful to some crops.

Energy requirements of manufacture

Solid NH_4NO_3 3.2 GJ per ton

(1gigajoule = 1×10^9 J)

Pollution problems in manufacture

(i) Oxides of nitrogen into air from nitric acid plant.

(ii) NH_4NO_3 particles emitted into air.

This is serious and must be controlled.

(See Monsanto advertisement, Background Paper 1).

TRANSPORT AND STORAGE

Ammonium nitrate is a strong oxidising agent. The presence of oxidisable substances can lead to spontaneous heating and decomposition.

$$NH_4NO_3(s) \longrightarrow N_2O(g) + 2\,H_2O(g) \qquad \Delta H = -23 kJmol^{-1}$$

starts at 185°C
violent at 250°C

$$N_2O(g) \xrightarrow{600^\circ C} N_2(g) + \tfrac{1}{2}O_2(g) \qquad \Delta H = -71 kJmol^{-1}$$

This problem is overcome by

1. reducing the porosity of solid ammonium nitrate sold as fertiliser;
2. strict observation of storage and handling regulations.

(See Storage Instructions, Background Paper 11)

ACTION AS FERTILISER

N in NH_4^+ is slowly converted to NO_3^-

$$NH_4^+ \xrightarrow[\text{in soil}]{\text{nitrifying bacteria}} NO_3^-$$

While this occurs NH_4^+ is held in the soil by adsorption on clay particles.

N in NO_3^- is immediately available to the plant.

N.B. If nitrate is not used quickly by growing plants there is a risk that it will be leached out of the root zone (i.e. washed out since it is very soluble) and will pass into water courses. Although this could result in pollution (eutrophication), it is not serious in the U.K. as our water courses are short and relatively swift-moving and few inland lakes are in areas of intense cultivation.

Agriculturalists are aware of this problem and it can be controlled by sensible use of fertilisers.
Considering the cost of fertilisers farmers are unlikely to apply more than their crops can use.

Challenge urea consultant:

Urea is converted into NH_4^+ by hydrolysis

$$NH_2CONH_2 \xrightarrow[\text{in soil}]{\text{enzyme UREASE}} (NH_4)_2CO_3$$

1. There will be delay in release of N to the plant while hydrolysis followed by nitrification is taking place.
2. Ammonium carbonate is unstable. What are the risks of loss of ammonia gas to the air with consequent loss of fertiliser N?

MARKET

Selling price

£110 per ton of ammonium nitrate (July 1981, U.K.)

Market Use

Ammonium nitrate has a wide range of application in agriculture throughout the world.

Market data

Production and consumption data are given on Data Sheet 5. For purposes of comparison both you and the urea consultant have the same data.

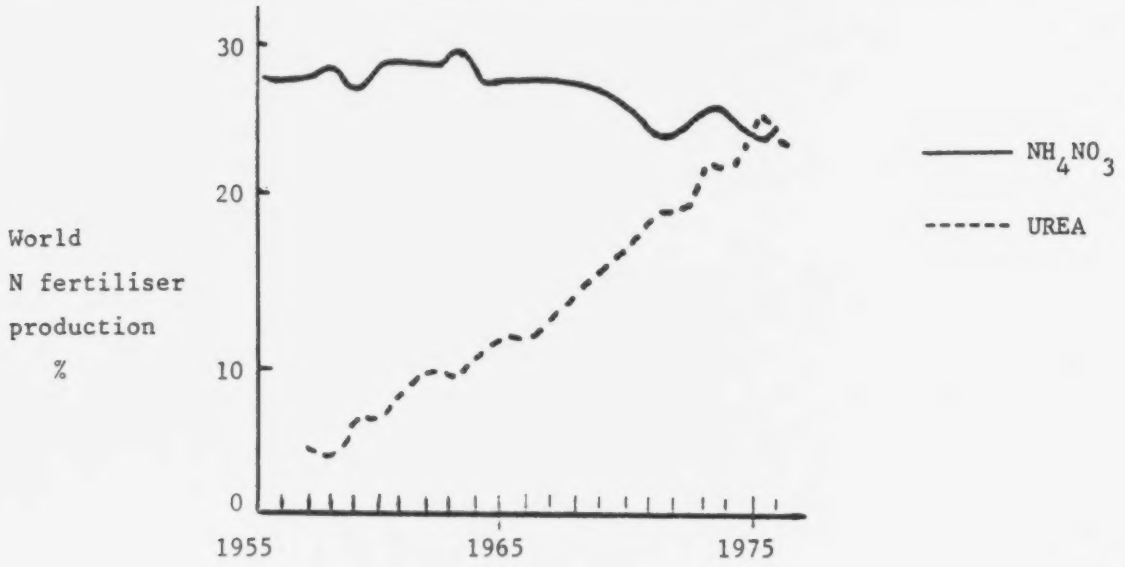
Study the data and prepare a brief summary for the industrialist. Do not overwhelm him with figures but try to provide him with the following information about ammonium nitrate:-

- its share of world nitrogen fertiliser production
- consumption trends (increasing/steady/decreasing)
- geographical variations in its use which support your case
- future market

> Challenge urea consultant:
>
> The export market looks tempting but what are the chances of developing countries starting up their own production or importing from nearer developed countries?
>
> (See Background Paper 111)

Market outlet other than as fertiliser

About 10% of total ammonium nitrate output is used in making explosives.



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*	U.K. All N fertilisers		1055	1045	1147	1222
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		Urea	854	662	1090	877
Latin America	Brazil	A.N.	76	76	107	110
		Urea	24	81	33	197
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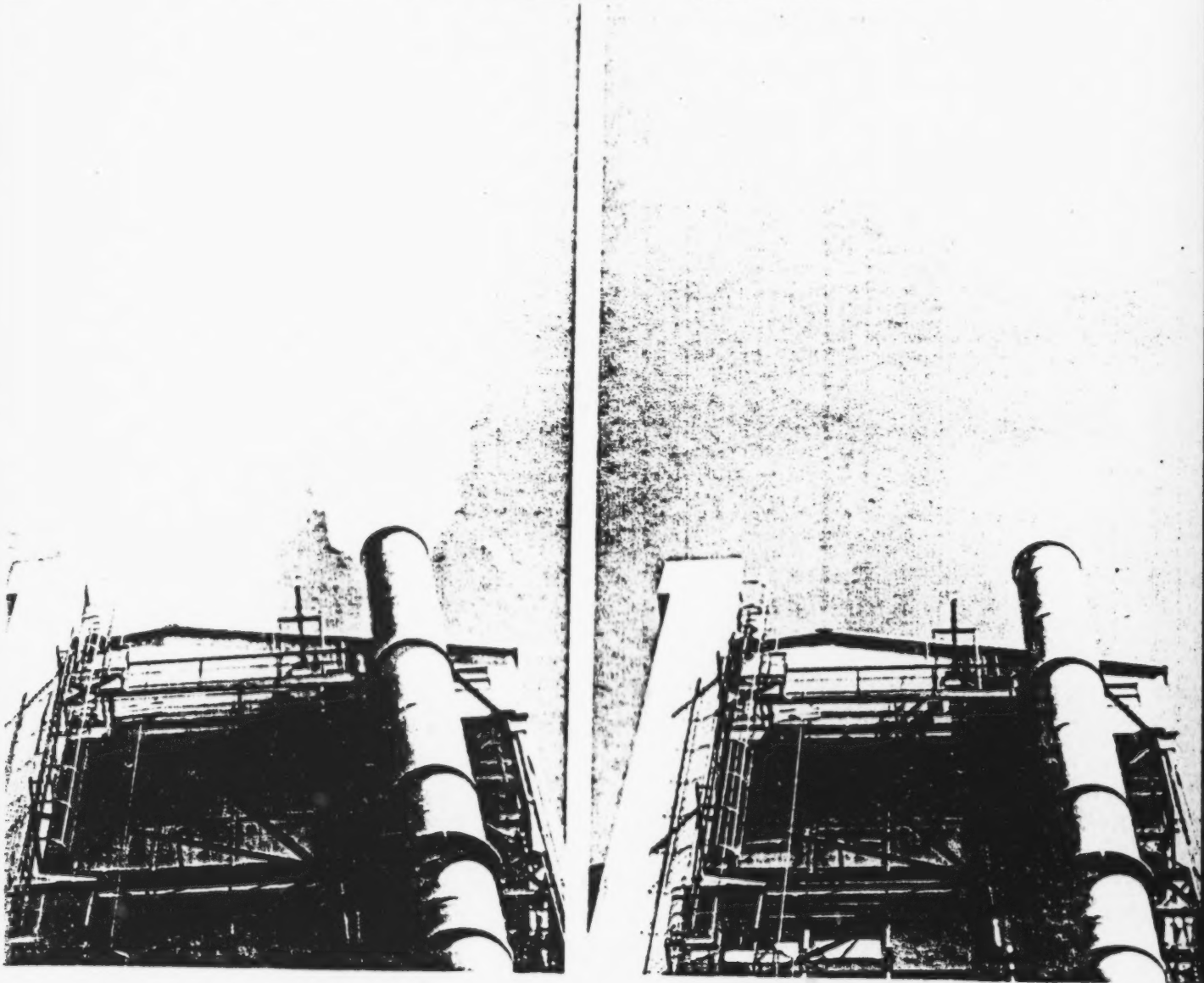
* Breakdown figures for U.K. are not available but the bulk of U.K.'s nitrogen fertilisers is based on ammonium nitrate.



When material costs are rising sky-high, the benefits of Monsanto Mist Eliminators are clear.

The exhaust plume on the left is more than just unsightly. It's downright wasteful.

Fortunately, there's a simple solution. The same stack is shown on the right, fitted with Monsanto Mist Eliminators.

Installing Monsanto Mist Eliminators has a dramatic effect on the exhaust of process gas in ammonium nitrate and urea plants.

Air pollution control is a further benefit. Plumes become virtually invisible, and emissions are easily within statutory limits.

Find out how Monsanto can tailor a Mist Eliminator system to your requirements. Contact Enviro-Chem Systems Dept., Monsanto Europe S.A., 270-272 Avenue de Tervuren, 1150 Brussels, Belgium. Tel:(02)-762.11.12. Telex 62927.

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Monsanto Enviro-Chem

BACKGROUND PAPER II

NH_4NO_3

The storage of Straight Ammonium Nitrate Fertiliser containing more than 28% N in merchants stores

Ammonium nitrate is widely used internationally in industry and agriculture. It is not itself combustible, but is an oxidising agent or strong supporter of combustion which can assist other materials to burn, even if air is excluded. It can melt if heated and may then give off yellow or brown fumes which are toxic.

Provided the following precautions are observed prilled ammonium nitrate in plastic bags can be handled and stored with complete safety.

THE FERTILISER MANUFACTURERS ASSOCIATION LIMITED

1 Ammonium nitrate must be stored only in bags supplied by the manufacturer.

2 Ammonium nitrate should be stored in buildings constructed of non-combustible materials. Galvanised sheeting is undesirable. The building must be capable of being well ventilated in the event of fire. There should preferably be no basement or upper storey. Drain openings should be protected so that molten ammonium nitrate cannot run into them. This will reduce the risk of pollution or of rapid decomposition in confined spaces.

3 Outside storage may be permissible with proper safeguards, subject to the approval of the manufacturer.

4 Stores and outside stacks should be protected from access by unauthorised persons and where necessary fenced against damage by animals.

5 Ammonium nitrate should not be stored near possible sources of fire or explosion (eg timber yards, major oil storage, gas lines).

6 Ammonium nitrate must not be stored within ½ mile of a hospital or institution which cannot be readily evacuated in the event of a fire.

7 7.1 There should be a readily accessible telephone.

7.2 The local fire service must be made fully aware of the store's facilities, the maximum tonnage of ammonium nitrate likely to be stored, and approve the adequacy of the local water supply for fire-fighting.

7.3 There must be adequate means of fighting any initial outbreak of fire eg small bore hose capable of reaching all parts of the storage area, water or CO_2 extinguishers. Chemical fire extinguishers must not be used in fighting fires involving ammonium nitrate.

7.4 Stores or sites holding large quantities may require to be equipped with an approved fire detection system or have continuous supervisory staffing for 24 hours a day. Manufacturers should be consulted.

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8 Ammonium nitrate must be kept completely clear of all sources of heat or flames.

9 Explosives, combustible materials, urea, acids, chlorates, chemicals, powdered metals, grain, feeding stuffs or fodder should not be stored in the same building as ammonium nitrate nor in such proximity that molten ammonium nitrate could come into contact with them. They should be so separated that they cannot contaminate the ammonium nitrate and that any fire or reaction in which they may be involved cannot affect the ammonium nitrate.

10 It is undesirable to store ammonium nitrate adjacent to compound fertilisers which may be capable of self-sustaining decomposition. Guidance may be obtained from the manufacturer.

11 Ammonium nitrate should never be mixed with any other product in the same stack.

12 Smoking must be forbidden in the ammonium nitrate storage area and prominent "No Smoking" notices must be displayed.

13 Vehicles or lifting trucks should not be allowed to remain in the store for long periods or at any time when the store is not manned unless separated by an approved fire barrier. Vehicles should not be parked overnight adjacent to outside stacks of ammonium nitrate.

14 Walls, floors and equipment must be kept clean. Spillage should be cleaned up at once and not allowed to remain on floors or equipment. Organic materials such as sawdust must not be used as an aid to cleaning floors. Sand, "oilsorb", or other similar materials should be used.

15 Damaged bags should be patched or put into overpacks. Contaminated products must be quickly and safely disposed of by eg burying, spreading thinly on open ground, or washing away, as permissible.

16 Stacks of ammonium nitrate must be arranged and sized to allow ready access. Individual stacks must not contain more than 300 tons. The height of the stacks must be such that they are at least 3 ft below eaves, beams and lighting fittings. There must be a walkway of at least 3 ft wide around each stack, and one passageway wide enough to provide vehicular access to each stack to facilitate dismantling in the event of

A QUICK ANSWER TO WORLD FAMINE

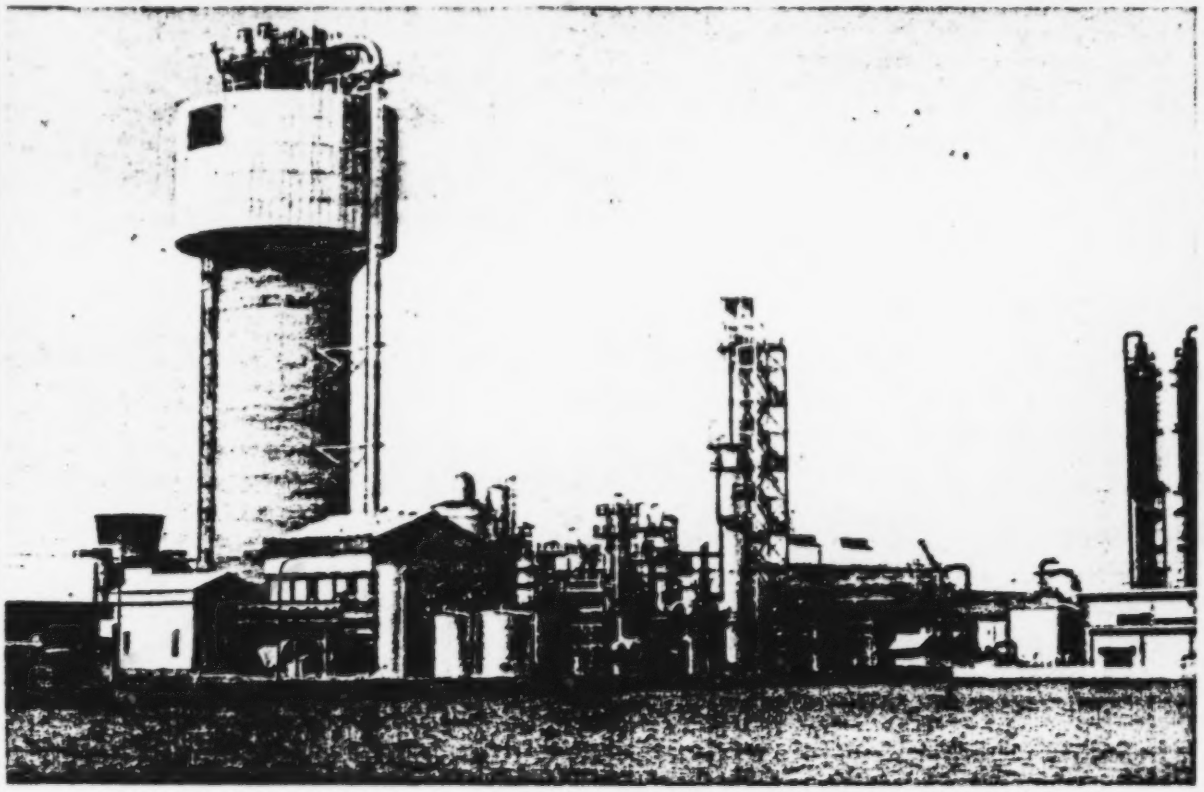

Photo: Courtesy of Southern Petrochemical Industries Corporation Ltd.

The world is now experiencing one of the most ravaging food shortages in history. We would like to offer encouragement to the many countries and international organizations that are doing an earnest job to alleviate the situation.

We would also like to take this occasion to introduce our urea manufacturing processes to those who are deadly serious in their efforts to produce more food for the underfed. Urea fertilizer represents the most effective first aid measure available for the purpose and can be produced easily for the immediate benefit of the wretched. In the present circumstances, urea fertilizer is a top priority requirement.

Needed quantities of high-quality urea can be obtained quickly and efficiently. The photo above shows the single-train 1,600-ton/day urea plant of Southern Petrochemical Industries Corporation Ltd. (SPIC) near Tuticorin, Tamil Nabu, India. We are proud to say that it was constructed from scratch to mechanical completion in an amazingly short period of 23 months. People everywhere now rely more than ever on such urea plants to supply this valuable plant nutrient.

Our newest process — the Mitsui Toatsu Total Recycle C-Improved Process — is incorporated in the SPIC plant. Facilities employing this process can be erected swiftly and economically . . . and they are easy to operate. They offer a quick answer to world famine. Our Total Recycle C and C-Improved Processes are utilized in 34 commercially-operated plants worldwide and 11 more are currently under construction. Wouldn't you like to be among those who are helping people help themselves? Why not begin by writing for our urea process catalog today?

MITSUI TOATSU CHEMICALS, INC.

P.O. Box 83, Kasumigaseki Bldg., Tokyo 100, Japan
Cable: "MITSUITOATSU TOKYO" Telex: 0222-3622 MTCHEM J

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SUMMARY SHEET

CONSULTANT

Use this sheet to help you organise your report for the industrialist

	My compound	Points to take up with the opposition
Production		
Transport and storage		

Summary Sheet contd

CONSULTANT

	My compound	Points to take up with the opposition
Action as fertiliser		
Present market		
Future market		

NITROGEN FOR THE NINETIES

Industrialist

You are operating in the U.K. and you already have an ammonia plant. You want to know whether it would be more profitable to convert the ammonia into ammonium nitrate or urea for sale as fertiliser.

$NH_3 \longrightarrow NH_4NO_3$ or $NH_3 \longrightarrow NH_2CONH_2$?

You have employed two consultants to give you advice, one on ammonium nitrate and the other on urea.

Session 1

Your consultants have all the data and are preparing their reports for you.

You should spend this session working out the questions to which you require answers in order to arrive at your decision. Your questions should cover the following areas:-

1. Production
2. Transport and storage of the product
3. Action of the product as fertiliser
4. Present market for the product
5. Future market.

Use Background Sheet 1 'Production and Marketing Problems' to help you devise detailed questions under each of the headings 1, 2, 4 and 5. List your questions on the Decision Sheet.

Although you are paying your consultants to supply the details, you need some background knowledge of the action of nitrogen fertilisers. Consult Background Sheet 2 'The action of nitrogenous fertilisers' for this.

Background Sheets 1 and 2 give you the essential information. There is nothing to stop you from going beyond this if you have time to find out more for yourself.

Session 2

Meet with your two consultants and ask each in turn for his report. (You may find it more satisfactory to have each report on a section at a time). Remember that each consultant will try to persuade you to follow his advice; be on the lookout for disadvantages he may be trying to disguise.

For each of the areas 1 - 5 weigh up the relative merits of the two compounds and decide which you think is the better. Finally, make your overall decision.

BACKGROUND SHEET 1 'Production and Marketing Problems'

The industrial chemist embarking on the manufacture and marketing of a new product must be reasonably sure that the venture will be profitable. (N.B. foot-note *)

Production problems

The industrialist must consider the need for extra plant, the availability of raw materials, the energy requirements of the process and the purity of the final product. He may be faced with extra expense on pollution control during manufacture. Although not essential, a known outlet for surplus intermediates would be a bonus.

Marketing problems

Transport and storage of the product must be considered in terms of safety and cost.

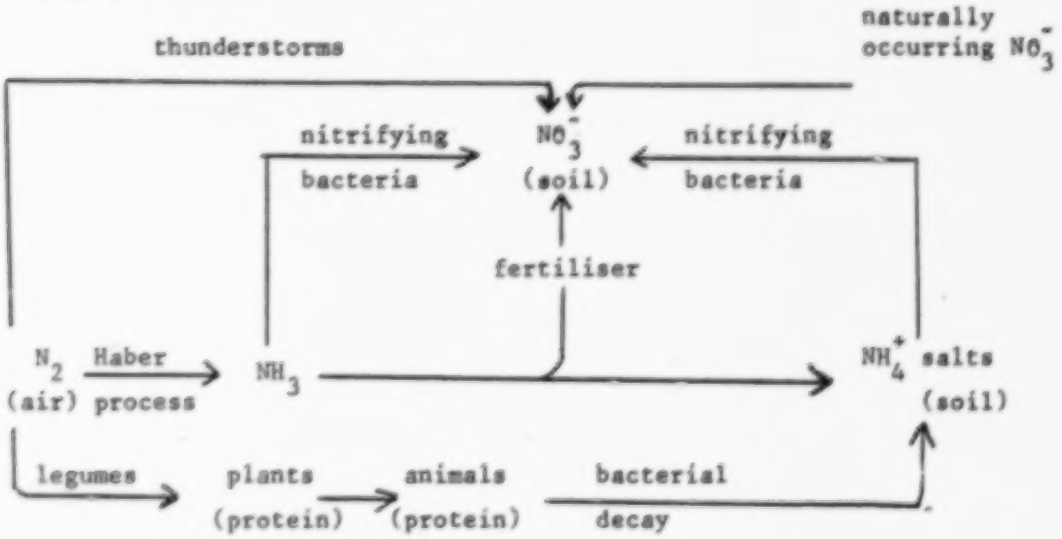
The main concern, of course, is the market for the product. The manufacturer must know its likely share of the world market, whether demand is steady and how the product stands in relation to its competitors. It may be that he has an advantage over his competitors in particular regions of the world. He must know the price he can expect to get and how this compares with the prices of competing products.

The market potential of his product in future years is vitally important. There are two possible markets - home and overseas - and the potential of both should be explored. A final decision to concentrate on the home market or to develop an export market must depend on the industrialist's interpretation of future demand. Also if, for some unforeseen reason, the market demand decreases he would feel more secure if he knew there were uses for his product other than the main outlet for which he intends it.

* In a real-life situation the industrialist would require a breakdown of actual costs for plant, labour, raw materials, transport etc. This is too complex for an exercise such as the one you are working on. Your consultants will give you the market price of the fertilisers but they cannot give you other costings. However they have ample information on manufacturing processes, pollution problems, transport, present and future markets and you must use your commonsense to infer that e.g. extra manufacturing stages, removal of pollutants etc will mean extra expenditure whereas costs will be offset by e.g. an alternative market for surplus product.

BACKGROUND SHEET 2. 'The Action of Nitrogenous Fertilisers'

The nitrogen cycle



Action of nitrogen compounds in the soil

Nitrogen becomes immediately available to the plant once in the form of nitrate.

Conversion of NH_4^+ to NO_3^-

Nitrification: $NH_4^+ \xrightarrow[\text{in soil}]{\text{nitrifying bacteria}} NO_3^-$

Reaction of urea

Hydrolysis: $NH_2CONH_2 \xrightarrow[\text{in soil}]{\text{enzyme UREASE}} (NH_4)_2CO_3$

Movement of nitrogen compounds in the soil

This is important because the nitrogen compounds must be available to the plants in the region of their roots.

The ammonium ion moves slowly because it is held in soil by adsorption onto clay particles.

Nitrate moves readily through soil and can be leached right out of it.

Urea moves only slightly less readily than nitrate (but think about the effect which hydrolysis will have on its rate of movement).

Background Sheet 2 contd.

Problems

(Think about these yourself and ask your consultants).

1. Is it desirable or undesirable to add nitrate directly in the form of ammonium nitrate?

2. Is it desirable or undesirable that urea undergoes a series of reactions before conversion of its nitrogen into nitrate?

3. Does unused fertiliser give rise to pollution problems?

DECISION SHEET

Write in your questions here	NH_4NO_3	Urea	Decision - on balance which seems better? Decide for each question separately.
Production			
Transport and storage			

Questions	NH_4NO_3	Urea	Decision
Action as fertiliser			
Present market			
Future market			

Decision Sheet contd.

Decision by section

	NH_4NO_3	Urea
1. Production		
2. Transport and storage		
3. Action as fertiliser		
4. Present market		
5. Future market		

FINAL DECISION:

PRODUCTION TEAM

Maisie Clubb
Kirsty Letton
Lorraine Logan
Alan Johnstone
Douglas McConnach

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